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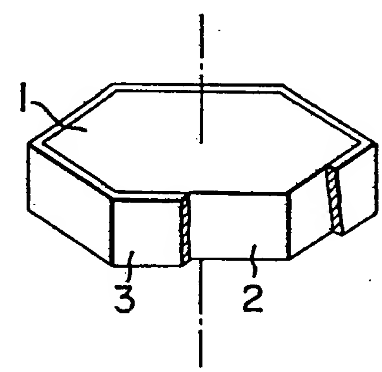
(54) **Polygonal mirror and method of manufacturing the same.**

(57) A polygonal mirror and a method of manufacturing the same are disclosed in which a machined mirror surface (2) of an aluminum substrate or block (1) is anodized to form a transparent film (3) for protecting the mirror surface (2).



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POLYGONAL MIRROR AND METHOD OF MANUFACTURING THE SAME

The present invention relates to a polygonal mirror and a method of manufacturing polygonal mirrors, and more particularly to a polygonal mirror for laser beam scanning suitable for use in a laser printer and others.

A conventional optical reflecting mirror is formed in such a manner that a surface of a glass or metal substrate is lapped to a mirror surface finish, the surface thus lapped is coated with evaporated aluminum or the like through the vacuum evaporation or sputtering technique to increase the reflectivity of the surface, and the surface is further coated with a protection film. In recent years, however, an increase in the accuracy of a turning (or cutting) machine and an improvement in a cutting technique with a diamond cutting tool make it possible to form an optical mirror surface by a cutting operation.

A substrate of a conventional optical element having a mirror surface is made of glass or a hard metal capable of being lapped. The surface of the optical element is coated with evaporated aluminum in order to increase reflectance, and is further coated with a thin film of SiO or SiO_2 for mechanical protection. In such an optical element, the film of SiO or SiO_2 on the glass or hard metal substrate has a large

mechanical strength and can serve as a protection film even when the thickness of each of evaporated aluminum and the film of SiO or SiO_2 is small because the mechanical strength of such a thin film depends on the hardness of the substrate.

However, such a conventional optical element is high in cost and low in handling efficiency since the element is required to have a high reflection coating or film and a film for mechanical protection of the surface.

An object of the present invention is to provide a polygonal mirror in which highly reflective surface is formed by directly machining (or cutting) a surface of a substrate or a block made of aluminum or an aluminum alloy such as an Aℓ-Mg alloy, an Aℓ-Mg-Si alloy or an Aℓ-Mn alloy.

Another object of the present invention is to provide a polygonal mirror which has a characteristic of high reflectance and is capable of producing a constant scanning light intensity in a range of scan angle.

Yet another object of the present invention is to provide a method for manufacturing such a polygonal mirror.

In order to attain these objects, a polygonal mirror according to the present invention is made of aluminum or an aluminum alloy, a reflecting surface of the mirror is cut to a mirror surface, and a protection

film is formed by anodizing the mirror surface.

The present invention will be apparent from the following detailed description taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a perspective view showing a main part of a polygonal mirror according to the present invention;

Fig. 2 is a diagrammatic view for explaining interference of light caused by a single layer of thin transparent film;

Fig. 3 is a graph showing a relation between film thickness and reflectivity; and

Fig. 4 is a graph showing the variation of reflectivity with film thickness for a plurality of values of incident angle.

In order to realize a highly reflective polygonal mirror by fly-cutting, soft metal such as aluminum or aluminum alloys can be used and machined to a mirror surface. In the case of such an mirror mode of soft metal, however, a thin film formed on the surface of the mirror cannot act as a protection film having a high mechanical strength. Accordingly, it is required to form a thick SiO or SiO_2 film on the surface. The SiO or SiO_2 film is small in growth rate and therefore it is inefficient to form such a film. Further, an apparatus for forming the above film is expensive, and in addition to this, handling efficiency is low.

In order to solve such difficulties, a polygonal mirror according to the present invention is made of aluminum or an aluminum alloy, and the reflecting surface of the mirror is fly-cut to a mirror surface. Further, the mirror surface thus obtained is anodized to form a film for mechanical protection.

As mentioned above, according to the present invention, a surface of an aluminum substrate or block is directly cut to a mirror surface, and therefore the high-reflectivity characteristic of aluminum is utilized effectively. Thus, it is not required to form a high-reflectivity film, but only a protection film is required. Moreover, a thin transparent film acting as the protection film can be advantageously readily formed on the aluminum substrate or block by anodic oxidation. In other words, one of the advantages of the present invention resides in that the anodic oxidation is applied as an otpical mirror surface processing to an aluminum substrate or block to which it has been hard to apply the optical mirror surface processing.

The use of anodic oxidation has the following advantages. That is, a thick film can be readily formed, and an anodic oxidation apparatus for forming such a film is simple in structure, as compared with an evaporation or sputtering apparatus. Further, the thickness of a film formed by anodic oxidation is proportional to the quantity of electricity having

flowed between electrodes, and therefore can be readily controlled. Thus, a protection film of good quality can be readily formed, and moreover the cost thereof can be reduced.

Now, a preferred embodiment of a polygonal mirror according to the present invention will be explained below, with reference to Fig. 1. In the figure, a block 1 of a polygonal mirror is made of aluminum or an aluminum alloy, the side surface of the block 1 is cut to mirror surfaces 2, and a thin transparent film 3 is formed by anodic oxidation to protect the mirror surfaces 2. The substrate 1 is preferably made of an Aℓ-Mg alloy, which is suited for anodic oxidation. In the present invention, the film 3 formed by anodic oxidation does not lower the high reflectivity of the mirror surfaces, and moreover mechanically protects the surface of the block 1 made of a soft metal such as aluminum. The thin transparent film 3 produces a light interference phenomenon in accordance with the thickness thereof, that is, the reflectivity of the film 3 varies with the film thickness. Further, in the case where the polygonal mirror is rotated to carry out optical scanning, the incident angle of light at each mirror surface 2 varies with the rotational angle of the polygonal mirror, and thus the film thickness in the optical sense in the protection film 3 varies with the above-mentioned rotational angle. A change in the optical film thickness in the protection film 3 causes

a change in the interference condition, and therefore the intensity of scanning light varies with the rotation of the mirror. The above-mentioned facts will be explained with reference to Fig. 2. In the figure, the thin transparent film 3 having a refractive index n_1 is formed, by anodic oxidation, on a mirror surface 2 of the aluminum block 1 having a refractive index n_o. Now, let us consider the case when a medium outside the film 3 has a refractive index n_2 equal to 1. Then, the intensity R of reflected light is given by the following equation:

$$R = \frac{r_1^{\,2} + r_o^{\,2} + 2r_1 r_o \cos \delta}{1 + r_1^{\,2} r_o^{\,2} + 2r_1 r_o \cos \delta}$$

where r_1 indicates the amplitude of light reflected from the upper surface of the film, r_o the amplitude of light reflected from the lower surface of the film, δ an angle equal to $4\pi n_1 d \cos \theta_r/\lambda$, θ_r an angle of refraction, d the thickness of the film 3 formed by anodic oxidation, and λ the wavelength of light.

When the factors n_o, n_1, n_2, θ_r and λ are kept constant, the intensity R of relfected light is a function of the thickness d of the film 3 and a periodic function with respect to optical film thickness $n_1 d$. In the case of normal incidence, the intensity R of reflected light varies periodically with the optical thickness $n_1 d$ of the film 3, as shown in Fig. 3.

In the present embodiment, the refractive

indices n_o, n_1 and n_2 have a relation $n_o > n_1 > n_2$, and therefore the film 3 can act as an antireflection film. As is apparent from Fig. 3, in order to make maximum the intensity of relfected light, it is necessary to make the optical film thickness n_1d equal to $m\lambda/2$. In a polygonal mirror for optical scanning, however, the optical film thickness n_1d for making maximum the intensity of reflected light is not constant, since the indicint angle θ of light at the upper surface of the film 3 varies with the rotation of the polygonal mirror.

Now, let us consider the case where the incident angle θ varies from θ_1 to θ_2 to obtain an optical scanning range. Then, the film thickness d for making maximum the intensity of reflected light varies from d_{θ_1} to d_{θ_2}, and the values d_{θ_1} and d_{θ_2} are given by the following equations:

$$d_{\theta_1} = \frac{m\lambda}{2n_1 \cos \theta_{r1}}, \quad d_{\theta_2} = \frac{m\lambda}{2n_1 \cos \theta_{r2}}$$

where $\sin \theta_1 = n_1 \sin \theta_{r1}$, $\sin \theta_2 = n_1 \sin \theta_{r2}$, $d_{\theta_1} < d_{\theta_2}$, and m is a positive integer other than zero.

Fig. 4 shows the variation of the intensity of reflected light with the optical film thickness for some values of incident angle. Referring to Fig. 4, when a reflecting mirror is rotated so that the incident angle is changed from θ_1 to θ_2, the optical film thickness for making maximum the intensity of reflected light varies with the above rotation. In more detail, for

the incident angle θ_1, the intensity of reflected light varies with the optical film thickness as indicated by a curve 6. On the other hand, for the incident angle θ_2, the intensity of reflected light varies as indicated by a curve 8. Accordingly, in the case where a reflecting mirror having the film thickness capable of making maximum the intensity of reflected light when light impinges upon the mirror at the incident angle θ_1, is rotated so that the incident angle is changed from θ_1 to θ_2, the intensity of reflected light varies from a point A to a point B. On the other hand, in the case where a relfecting mirror having the film thickness capable of making maximum the intensity of reflected light when light impinges upon the mirror at the incident angle θ_2 is rotated, the intensity of reflected light varies from a point D to a point C.

For an incident angle θ_o corresponding to the the center of the optical scanning range, the intensity of reflected light varies with the optical film thickness as indicated by a curve 7. When the thickness of the film takes a value d_{θ_o} in order for the intensity of reflected light to be maximum at the incident angle θ_o, the variation of the intensity of reflected light with the incident angle can be made smallest as shown in Fig. 4, that is, the intensity of reflected light varies only in a range from a point E to a point F. Accordingly, the optical thickness of the film is set so that the intensity of reflected light is maximum at

the incident angle θ_o corresponding to a central portion of the optical scanning range, that is, is made equal to $n_1 d_{\theta_o}$ (= $m\lambda/2 \cos \theta r_o$).

As has been explained in the foregoing description, according to the present invention, a protection film is high in transparency, and therefore the thickness of the film can be made large to increase the mechanical strength thereof, thereby producing a remarkable protection effect. Further, since the film is formed by anodic oxidation, the growth rate of the film is high. Furthermore, the film can be formed without using expensive apparatuses such as an evaporation apparatus and a sputtering apparatus, and therefore a polygonal mirror according to the present invention is advantageous from the economical point of view.

CLAIMS:

1. A polygonal mirror comprising:

a block (1) having a surface (2) machined with precision to mirror, said block being made of aluminum or an aluminum alloy; and

a transparent film (3) formed by anodizing said surface (2) machined with precision to mirror and used as a protection film for said mirror surface (2).

2. A polygonal mirror according to Claim 1, wherein said transparent film (3) has a thickness of $m\lambda/2n_1 \cos \theta_{r_o}$, where θ_{r_o} indicates an angle of refraction of incident light corresponding to a central portion of an optical scanning range, n_1 a refractive index of said transparent film (3), λ a wavelength of light and $\underline{m}$ a positive integer other than zero.

3. A polygonal mirror according to Claim 1, wherein said aluminum alloy further contains at least Mg.

4. A method for manufacturing a polygonal mirror comprising the steps of preparing a block (1) of aluminum or an aluminum alloy, cutting said block to provide a mirror surface (2) thereon, anodizing said block for forming a transparent film on said mirror surface to thereby protect said mirror surface.

FIG. 1

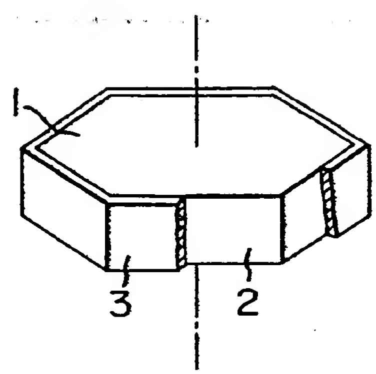


FIG. 2

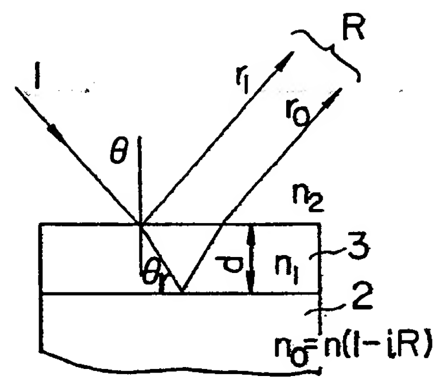


FIG. 3

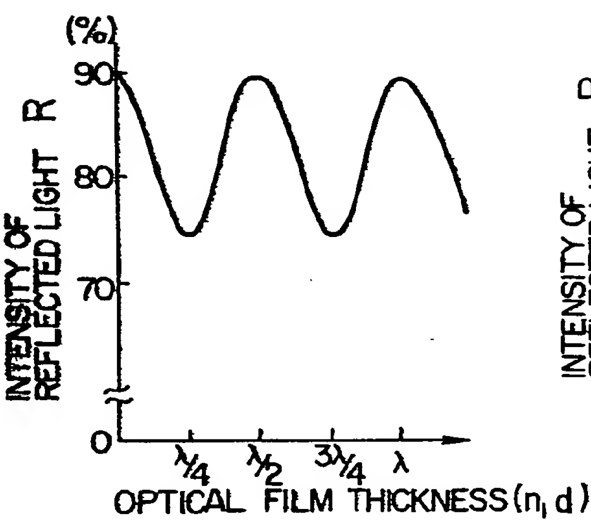
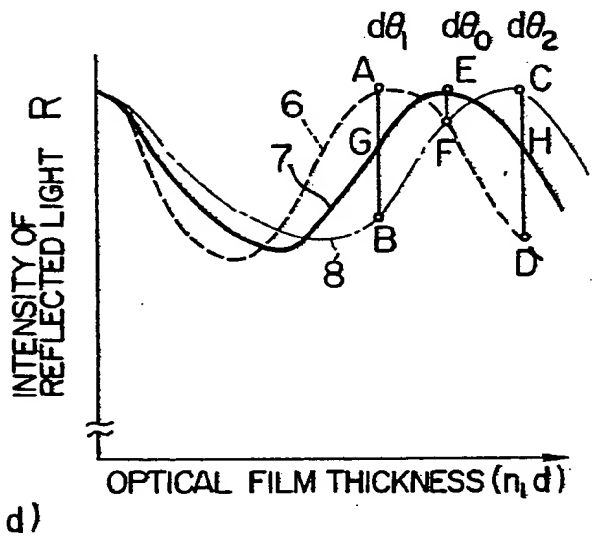


FIG. 4



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EUROPEAN SEARCH REPORT

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Application number

EP 83 10 3960

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
Y	FEINWERKTECHNIK & MESSTECHNIK, vol. 88, no. 7, 1980 M. KUPKA et al. "Diamantfräsen hochgenauer Metallspiegel", pages 346-350, chapter 2.9 ---	1,4	G 02 B 5/18
Y	APPLIED OPTICS, vol. 18, no. 23, 1979 F. COOKE "Generation of a spherical mirror in aluminum", pages 3878, 3879 ---	1,4	
Y	APPLIED OPTICS, vol. 17, no. 14, 1978 J. T. COX et al. "Protected Al mirrors with hi gh reflectance in the 8-12-micron region from normal to high angles of incidence", pages 2125, 2126 ---	1	TECHNICAL FIELDS SEARCHED (Int. Cl. 3)
A	DE-C- 110 178 (C. ZEISS) * Claim 1 * -----	1,3	G 02 B 5/08

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	25-07-1983	FUCHS R

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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